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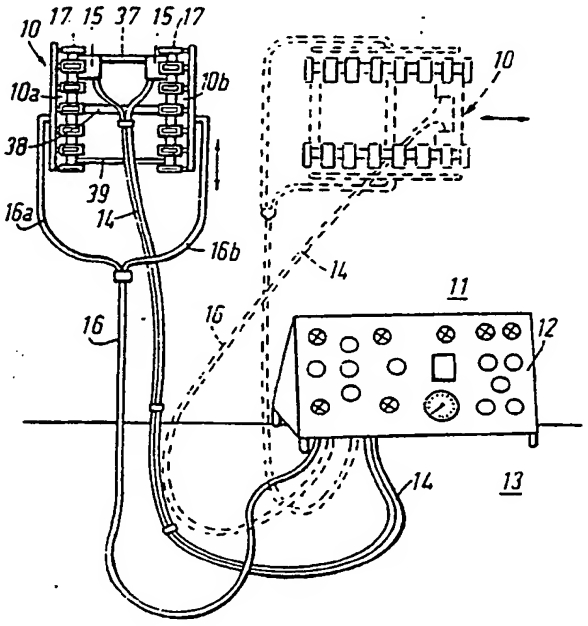
(54) Title: VEHICLE

(57) Abstract

A vehicle (10) which is especially designed for carrying equipment for treating plane or curved or double-curved surfaces. The vehicle is provided with suction cups (17) for maintaining the vehicle pressed against a vertically extending or oblique downwardly sloping or downwardly facing surface. The vehicle is provided with power-driven drive belts each with its respective set of suction cups (17) arranged in series. Furthermore, the vehicle has valve control devices which activate the suction cups in the positions where the drive belt is to form an abutment against the drive base-forming surface and inactivate the suction cups in the positions where the drive belt is to be released from abutment against the drive base.



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VEHICLE

The present invention relates to a vehicle which is especially designed for supporting equipment for treating plane or curved or double-curved surfaces, the vehicle being provided with suction cups for holding the vehicle pressed against a vertically extending or oblique downwardly inclining or downwardly facing surface (wall, under-ceiling or the like).

Preferably, the vehicle according to the invention is remotely controlled, so that it can be operated like a robot. If necessary, the vehicle can also carry with it driver or crew for operating equipment which the vehicle brings with it and in this connection the vehicle can, if desired, be manually controlled. The vehicle can be considered applicable for many different fields of use, but is regarded as finding its greatest employment as robot for driving on vertical or obliquely fashioned surfaces or downwardly facing surfaces. It is particularly appropriate to use the vehicle in conjunction with equipment which is to be utilised in the treatment of surfaces, that is to say in the treatment of internal and external surfaces of a storage tank or in other building constructions or on ships, rigs and the like. A special objective is a vehicle which can be used independently of working scaffolding or similar complicated devices for carrying or support. It can be especially appropriate to allow the vehicle to form carrying and supporting means for treating equipment such as sabd-blasting, rust-scaling and spraying equipment. The spraying equipment can be employed for spraying on paint or other cotaing agent on the surface which is to be treated, that is to say on the drive base itself. Alternatively, the vehicle can be adapted to transport crew for inspection of the surface which is to be driven on or for carrying out welding operations or other operation where a need arises for manual effort.

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Previously known vehicles for the afore-mentioned purposes have been burdened with various deficiencies and disadvantages, which result in the vehicle having restricted possibilities for use, this being especially applicable in cases where the drive base is uneven, for example, has a relatively heavily curved or double-curved shape.

Vehicles are, for example, known which are maintained on a base by means of magnetism (electro-magnetism). The use of the vehicle is restricted in such instances to apply to magnetisable drive bases. There are employed, for example, drive wheels and/or support wheels having roller surfaces which can create magnetic contact directly with the base. One is heavily dependent upon an even base without plate edges or other non-uniformities where breakage of the contact surface can readily occur and, in addition, one is dependent upon extra safety means to ensure that the vehicle is in place on the drive base.

Vehicles are also known which are pressed against a surface which is to be treated, by means of suction power. The vehicle can have, for example, a suction pipe the air intake opening of which is arranged as a narrow gap between the suction pipe and the surface which is to be treated. In such a case, one is dependent upon a constant air stream which is sucked through the narrow gap and which creates sufficient vacuum in the suction pipe to press the latter against the drive surface. This suction power can certainly readily maintain the vehicle pressed against a vertical surface in order to provide support abutments between the wheels of the vehicle and the drive surface, so that the vehicle can be guided in a controlled manner along the drive surface, but, on the other hand, is not in a position to carry alone the weight of the vehicle or the weight of the vehicle with associated equipment. Extra support devices have been proposed, for example, in the form of elongate

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frameworks which carry the vehicle at the lower end of the framework, while the framework is supported from above on, for example, the ship's deck or on a similar support-forming base. The extra support devices involve large complications for using the vehicle and result, in addition, in big purchase costs.

Devices are also known consisting of two cooperating frameworks which are displaceable backwards and forwards relative to each other. Each framework is provided with its set of suction cups which can be sucked fast to the base and hold the respective framework in place on the base, while the remaining framework, after its suction cups have eleminated the suction action, is transferred to a new position and the suction cups are sucked fast in the new position. Afterwards the first-mentioned framework can, after its suction cups have nullified the effect of suction, be drawn behind to its new position and its suction cups sucked fast in the corresponding new position. With such a device, a rectilinear movement can be effected along the surface which is to be treated, but in such a case one is dependent upon an intermittent pattern of movement, something which can be rather complicating and little suited as a pattern of movement for the accompanying equipment, since during such movement one only has the support of the one framework. In practice, it has been necessary to utilise separate means for local movement of the equipment in the framework while both of the latter are fixed, something which, in turn, demands frameworks of large and complicated design.

The vehicle according to the invention is characterised in that the vehicle is provided with one and preferably a pair of power-driven drive belts with suction cups arranged in series and that the vehicle has valve control means for activating the suction cups in positions where the drive belt is to form an abut-

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ment against the drive base-forming surface and for inactivating the suction cups in positions where the drive belt is to be released from abutment against the drive base.

By utilising according to the invention a relatively large number (for example, twenty-one) suction cups on each drive belt, there is the possibility of maintaining the vehicle in a secure manner simultaneously at several different locations along the path of movement of the drive belt, for example via one third of the total number of suction cups (say, via seven suction cups), while the remaining suction cups can occupy an inactive position or can occupy a transition position close by the suction cups which take up an active sucking position. By employing a relatively large number of active suction cups there is the possibility, even if one or a couple of the suction cups should suck false air as a consequence of unevenness in the base or for another reason, of ensuring a sufficiently large holding force via the remaining suction cups to maintain the vehicle safely and pressed against the base. At the same time, there is the possibility of allowing, one after another, a rearmost suction cup to nullify the suction effect simultaneously as a foremost suction cup which is led into place in the suction position is activated for suction action, so that the holding engagement can be displaced and at the same time movement in the drive belt can be allowed and thereby the vehicle can be permitted to drive in the longitudinal direction of the drive belt along the drive base in a safe and controlled manner. The speed can ba adapted according to the speed of working of the treatment equipment.

In order to obtain a correct starting up of the suction effect at the front of the vehicle and elimination of the suction effect at the rear of the vehicle it is necessary to have valve controls which

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respectively activate and inactivate the suction cups singly at specific positions of the vehicle, that is to say at specific positions of the drive belt of the vehicle. The control of the valves can be effected by means of mechanical, electromagnetic or other suitable actuating means which, in turn, can be controlled by mechanical control means or preferably program-controlled control means.

In order to ensure an accurate engagement between the vehicle and the drive surface in any phase of the forwardly driving movement of the vehicle, it is preferred that a forward suction cup is brought into position in support abutment against the drive base approximately at the same time as the suction cup is activated. In practice, it is of considerable importance that the suction cup immediately before it is brought into supporting abutment with the drive base occupies such a position that it can be placed momentarily under vaccum immediately the support abutment is established. In this connection, it is decisive that devices are employed which ensure a positive engagement between the drive base and a foremost, activated or activable suction cup in an intended engagement position. By activating the foremost suction cup while it is controlled in such a positive manner a force can be produced which in a reliable manner provides for drawing the vehicle against the drive base at the upper end of the vehicle, where a largest weight moment acts on the vehicle and where the vehicle can most easily slip free from the drive base when the vehicle is moved along the latter.

Further features of the vehicle according to the invention appear from the following description with reference to the accompanying drawings, in which:

Fig. 1 shows schematically the vehicle according to the invention during use on a surface which is to be treated.

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Fig. 2 shows on a larger scale the drive belt of the vehicle in a side view, with suction conduits and the like omitted for the sake of simplicity.

Fig. 3 shows the vehicle in a perspective view.

Fig. 4 shows in a perspective view details of the vehicle.

Fig. 5 shows a detail of the suction conduits.

In Fig. 1 there is illustrated in full lines a robot-forming vehicle 10 according to the invention which is moved along a vertically extending wall 11 in a vertical direction along the wall. In broken lines the vehicle is illustrated in another position for movement of the vehicle in a horizontal direction along the wall.

A control desk 12 having operating buttons, measuring instruments, control lamps and the like on its top and having a vacuum unit and the like arranged internally therein, rests on a floor surface 13 at the lower end of the wall 11.

From the control desk 12 there extend electrical leads 14 to two drive motors 15 shich are fastened to their respective sections 10a and 10b of the vehicle 10 and a main vacuum conduit 16 to two series of suction cups 18 on the vehicle. The series of suction cups are arranged on their respective sections 10a and 10b of the vehicle.

The vehicle 10 is designed as a belt vehicle with two separate drive belts which can be driven separately or at the same time forwardly in the drive direction of the respective drive motor 15 and which are adhered to the drive base or the wall 11 by means of their respective series of suction cups 18 included in the respective drive belt. It is possible to effect a certain control of the vehicle by intermittent operation of the two drive belts of the vehicle.

In Fig. 2 and 3 there are shown further details of the drive belts of the vehicle 10 with associated

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suction cups 18. The drive belt consists of a link chain 20 which passes over a motor-driven rotary toothed wheel 21 at one end of the vehicle and over a free-running rotary toothed wheel 22 at the opposite end of the vehicle. On one run of the drive belt which faces towards the drive base there are arranged two free-running control wheels 23, 24 which are arranged at a suitable distance from the respective adjacent rotary wheels 21, 22. Provision is made for the chain of the drive belt to pass, in relation to the drive base, rectilinearly between the control wheels 23, 24 and from these obliquely outwards over a distance of approximately the longitudinal dimension of a suction cup towards the rotary wheels 21, 22, so that only the suction cups between the control wheels 23, 24 occupy active suction positions against the drive base. The said angle is preferably only some few degrees.

The drive motors 15, which preferably consist of electromotor with reversible drive direction, are connection via an alternator 25 (Fig. 3) to their respective rotary wheels 21 in their respective vehicle sections 10a and 10b.

To the chain of the drive belt there is fastened via its respective one chain link a suction cup 18 in rigid connection with the chain link, so that the suction cup is moved together with the drive belt in the same pattern of movement as the associated chain link. In other words, provision is made for the path of movement of the suction cup 18 to be established precisely by the path of movement of the chain link. It is evident from Fig. 3 that each suction cup has an elongate form transversely of the longitudinal direction of the chain 20. Each suction cup projects a considerable distance laterally outside the chain 20 on opposite sides of the latter, while provision is made for a certain distance between the suction cups in the longitudinal

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direction of the chain. The intrinsic rigidity of the chain ensures that each suction cup 18 can only be pivoted by quite small angular blows about the longitudinal axis of the chain relative to the neighbouring suction cups 18 on the chain 20.

In the embodiment shown each suction cup 18 is only fixed to the chain 20 at the centre of the suction cup, so that the suction cup can be pivoted about the pivot axes of the chain link substantially with pivotal angles corresponding to the associated chain link relative to the neighbouring links in the chain. At the same time, the individual suction cup will not influence to a significant degree either, the path of movement of the chain. With normal chain tautening there will be ensured an accurately established pattern of movement for the suction cups over the rotary wheels 21, 22 and the control wheels 23, 24. The positioning of the control wheels 23, 24 in relation to the rotary wheels 21, 22 serves to establish an accurate guiding of the suction cups in the region between a rotary wheel and an adjacent control wheel in order to ensure thereby a favourable abutment between the suction cup and the drive base immediately ahead for activating the suction cups with a vacuum at opposite ends of the vehicle and for driving forwards and backwards.

The suction cups are constructed of a substantially rectangular support plate having a correspondingly shaped peripheral lip of elastically yielding material. At the one end of the support plate, just inside the peripheral lip, there is drilled in the support plate a suction opening which communicates on the outer side of the suction cup with a three-way valve 26 with assicuated valve slide 27. One passage of the valve communicates with the suction opening of the suction cup 18, and its second passage communicates with a vacuum conduit 28 via an associated

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BNSDOCID: <WO___8502135A1_I_>

branch conduit 29, while its third passage communicates with the outside air (atmospheric pressure). In one outer position of the slide 27 the first passage is placed in communication with the said second passage and in the second outer position the first passage is placed in communication with the said third passage, so that the suction cup can, alternately, be placed momentarily under vacuum and momentarily relieved of vacuum.

As shown in Fig. 4 each valve 26 communicates with the vacuum conduit 28 via a transverse branch conduit 29, the vacuum conduit 28 being designed in closed annular form via two of the passages of a T-shaped coupling union 30. The third passage of the coupling union 30 is taken up in a turning link 31 in connection with the outer end of an associated branch conduit 16a (and 16b) from the main vacuum conduit 16, so that the vacuum conduit 28 with the associated branch conduits 29 can be rotated about the turning link 31 in step with the rotation of the drive belt.

The drive belts are supported in their respective rigid drive belt frame 32 which determines the distance between the rotary wheels 21, 22 and the positioning of the control wheels 23, 24 relative to the rotary wheels. As shown in Fig. 2 the frame 32 is provided in the region between the control wheels 23, 24 with an extra, relatively rigid guide rail 33 which forms a local guiding engagement with the suction cups 18 via a support lug 34 for each suction cup. The guide rail forms on its one side guidance for the support lug and on the opposite side guidance for the suction cup itself with a moderate clearance for both the support lug and the suction cup. As shown in Fig. 4 the support lug 34 is fixed to the chain itself at a distance of the length of a link from the fastening of the suctiin cup on the chain. By means of the support

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lug 34 and the associated guide rail 33 there is ensured a positively controlled movement of the chain and at the same time a corresponding positively controlled movement of the suction cups 18 in the region between the control wheels 23, 24, so that the suction cups can be moved in an accurately determined manner in the region at and between the control wheels 23, 24. Provision is made for the guide rail to extend only so far in front of the control wheels 23, 24 so that the region, especially just by the control wheels, can subject the chain and the suction cups to a corresponding positively controlled movement. In this way. it is ensured that the suction cups - almost independently of the condition of the base - can guarantee an accurate, positively controlled movement towards and away from the drive base in order to attain thereby a controlled and safest possible engagement with the base. It is evident from Fig. 2 that the guide rail 33 is fixed only at the outer ends, so that the rigidity of the guide rail is greatest where the suction cups occupy their transition position between the active and inactive sucking position. In the region between the outer ends a certain bending is permitted of the guide rail 33, so that it can allow the suction cups with associated chain to conform to possible curves on the surface which forms the drive base.

In Fig. 4 there are shown two opposite guide chambers 35, 36 which project inwardly into the path of movement of the valve slide 27 and which ensure a mechanical readjustment of the valve slide 27 between its two outer positions. The guide chambers 35, 36 are shown arranged just by an associated control wheel 24, so that the momentary changing over of the individual suction cup from vacuum to atmospheric pressure is obtained just by the control wheel 24. Instead of the illustrated mechanical control device there can be employed, for example, an (EDB-) program-controlled

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control means with, for example, an electro-magnetically or pneumatically driven actuating means.

The vehicle according to the invention is, as mentioned, designed in two separate sections 10a and 10b which are connected to each other via transverse frame beams 37, 38, 39 which establish the distance between the sections and reinforce the sections relative to each other. The sections 10a and 10b are readily dismountably fastened to the frame beams 37-39, so that the latter can be replaced with longer or shorter frame beams as required and all according to the condition of the drive surfaces which are to be treated and, for example, in order to take up flanges or similar projections from the surface which is to be treated between the sections or in order to carry different types of tools between the sections.

The ready dismountability of the sections 10a and 10b also makes it possible on despatch of the vehicle to pack the vehicle in an especially space-saving manner. Also it is especially advantageous that the sections in a dismantled condition, where they demand little space, can be guided in an easy manner down into tanks or similar spaces via man holes or similar narrow passages. Nevertheless, the vehicle can provide, in a mounted condition, a relatively large support region for the vehucle during use.

Certainly, it is possible, by separate, intermittent operation of the belts of the vehicle relative to each other, to effect a certain correction of the direction of movement of the vehicle, that is to say to effect a certain control of the vehicle on the base. In order to be able to effect greater changes of direction there can be considered the use of a suction cup which is placed centrally in the vehicle and which can be moved separately towards and away from the drive base and which, in addition, is pivotably mounted about a central axis which extends at right angles to the

BUREAU OMPI WIPO INTERNATIONAL

BNSDOCID: <WO___8502135A1_I_>

drive base. After this extra suction cup is sucked fast to the drive base, one must thereafter, by means of extra control devices (not shown), discharge the vacuum in the suction cups of the drive belts. Thereafter, by driving the drive belts in opposite directions the vehicle can be turned about the extra suction cup. After the vehicle is swung through a suitable pivotal arc, the suction cups of the drive belts can be sucked fast again to the drive base and thereafter the vacuum in the extra suction cup can be discharged.

Consideration can also be given to designing the vehicle with two sets of drive belts, that is to say a first set of drive belts with associated suction cups as is shown in the drawings and a second set of drive belts with corresponding suction cups arranged in a direction transversely of the illustrated drive belts, that is to say with an extra drive belt just in front and an extra drive belt just behind the drive belts illustrated in the drawings. By means of pressure medium cylinders or similar control devices, the extra set of drive belts with associated framework, drive motor and the like can be moved towards and away from the drive base relative to the vehicle remaining, and in a manner corresponding to that described for the afore-mentioned extra suction cup, the suction cups of the extra drive belts can be placed under vacuum and the vacuum of the remaining suction cups of the vehicle discharged. Finally, by means of the pressure medium cylinders or by means of pressure springs or other devices, the drive belts can be pushed with the inactivated suction cups a suitable distance outwardly of the drive base, so that the vehicle can be moved in a direction across the direction of drive of the released drive belts. In other words, with the two sets of drive belts the drive can be easily rearranged from a drive pattern as illustrated in full lines in Fig. 1 to a drive pattern as illustrated by broken

BUREAU OMPI W.P.O INTERNATIONAL

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lines in Fig. 1.

In order that the vehicle will more readily conform to curves or similar obstacles on the drive base, the frame 32 can be linked at the centre.

In the illustrated embodiment a vehicle is shown with two drive belts, but vehicles can also be considered with only one drive belt, but then preferably a drive belt with two link chains arranged laterally displaced relative to each other. There can also be considered several drive belts rather than two on each vehicle. Instead of link chains, there can be employed, for example, belt bands or, if desired, a linked band construction.

BUREAU OMPI WIPO INTERNATIONAL

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CLAIMS:

1. Vehicle (10) which is especially designed for carrying equipment for treating plane or curved or double-curved surfaces, the vehicle being provided with suction cups (18) for holding the vehicle pressed against a vertically extending or oblique downwardly inclining or downwardly facing surface (wall 11, under-ceiling or the like), the vehicle (10) having at least one power-driven drive belt with suction cups (18) arranged in series, and valve control devices (26, 27, 35, 36) for activating the suction cups (18) in positions where the drive belt is to form an abutment against the drive base-forming surface (11) and for inactivating the suction cups in positions where the drive belt is to be released from abutment against the drive base, characterised in that the drive belt consists of a link chain (20) and a series (17) of suction cups (18) each of which is rigidly connected to its respective link of the link chain (20) and which are only connected to certain links of the link chain and project outwardly a considerable distance in front of the link chain so that each suction cup (18) as a consequence of the intrinsic rigidity of the chain can only be subjected to a limited pivoting about the link axes of the associated chain link and about an axis in the movement direction of the drive belt.

2. Vehicle according to claim 1, characterised in that the vehicle is provided with devices (23, 24; 33, 34) for ensuring a positive engagement between at least certain activated and/or immediately activatable suction cups (18).

BUREAU OMPI WIPO INTERNATIONAL

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3. Vehicle according to claim 1 or 2, characterised in that the vehicle is provided with two drive belts each of which is arranged on a drive belt frame (32) and each of which has its respective drive mechanism (motor 15 and the like) with rotary wheels (21, 22) and support wheels (23, 24) and its respective set of individually activable and inactivable suction cups (18), to form two separate vehicle sections (10a, 10b), the vehicle sections being readily dismountably connected two each other by way of transverse reinforcing member (36, 37, 38) which can form carriers for treating equipment and the like which can be carried with the vehicle.

4. Vehicle according to claim 1, 2 or 3, characterised in that the number of links in the link chain is far larger than the number of suction cups fastened to the link chain.

5. Vehicle according to claim 1, 2, 3 and 4, characterised in that the link chain (20) is extra reinforced in the abutment region of the drive belt against the drive base surface by way of a guide rail (33) fixed to the drive belt frame (32).

6. Vehicle according to claim 5, characterised in that the guide rail (33) is received between the suction cup (18) and a support lug (34) fixed to the link chain approximately at a distance of a link member from the link to which the associated suction cup (18) is fixed.

7. Vehicle according to any of claims 1 - 6, characterised in that the link chain (20) in the region of abutment against the drive base surface passes substantially rectilinearly between two support wheels (23, 24) and from the support wheels passes obliquely

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outwards from the drive base surface towards the rotary wheels (21, 22) of the link chain over a distance of at least the dimension of one suction cup in the drive direction.

8. Vehicle according to any of claims 1 - 3, characterised in that the suction cups (18) on each drive belt are connected via respective three-way valves (26) and an associated branch conduit (29) having an annular, flexible vacuum conduit (28) adapted to be subjected to a rolling movement corresponding to the drive belt, and the vacuum conduit being turnably mounted via a coupling union (30) at the end of a main vacuum conduit (16).

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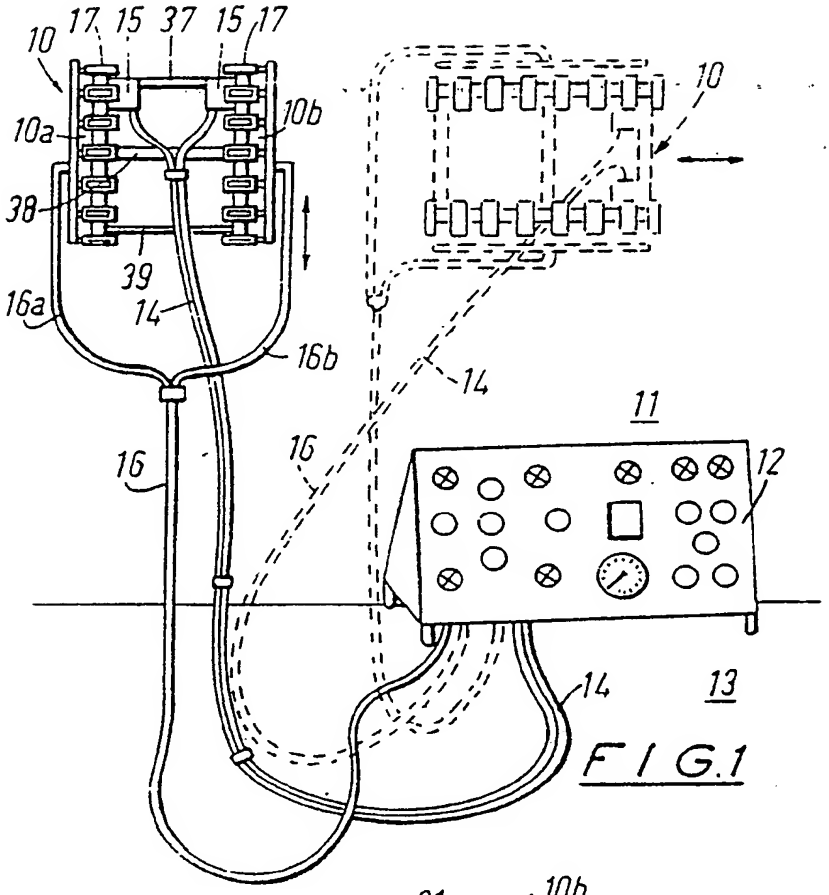

FIG.1

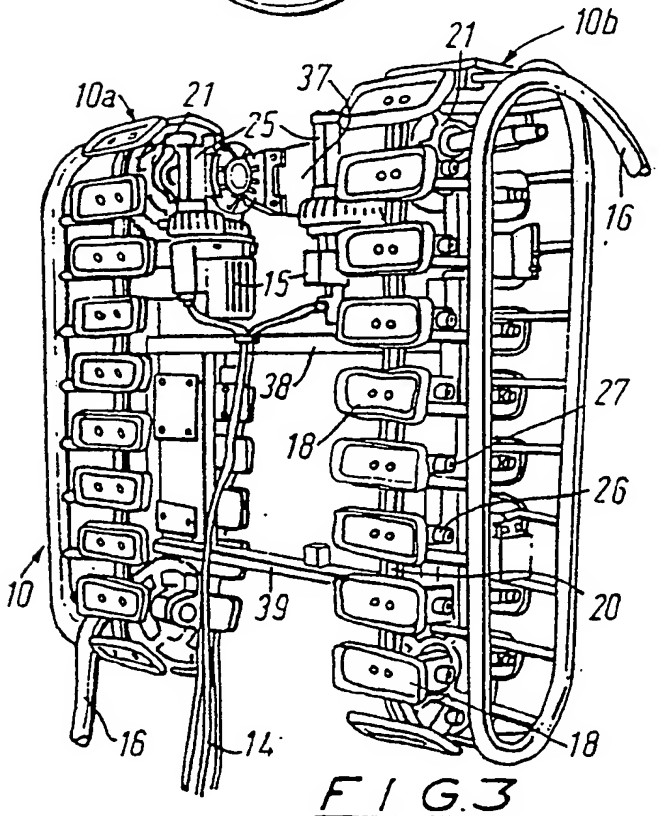

FIG.3

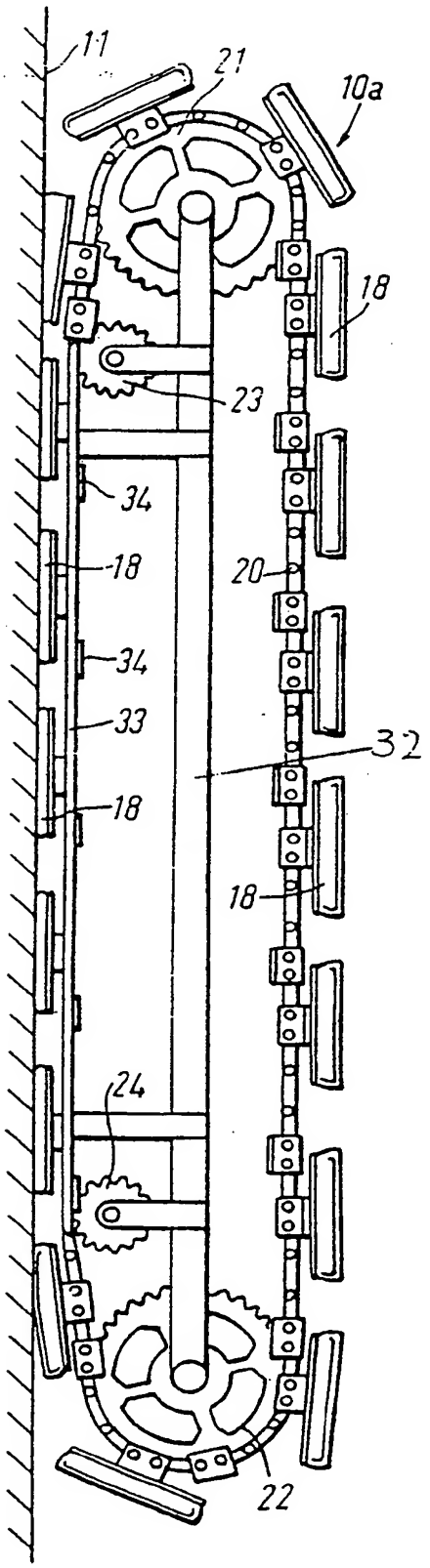

FIG.2

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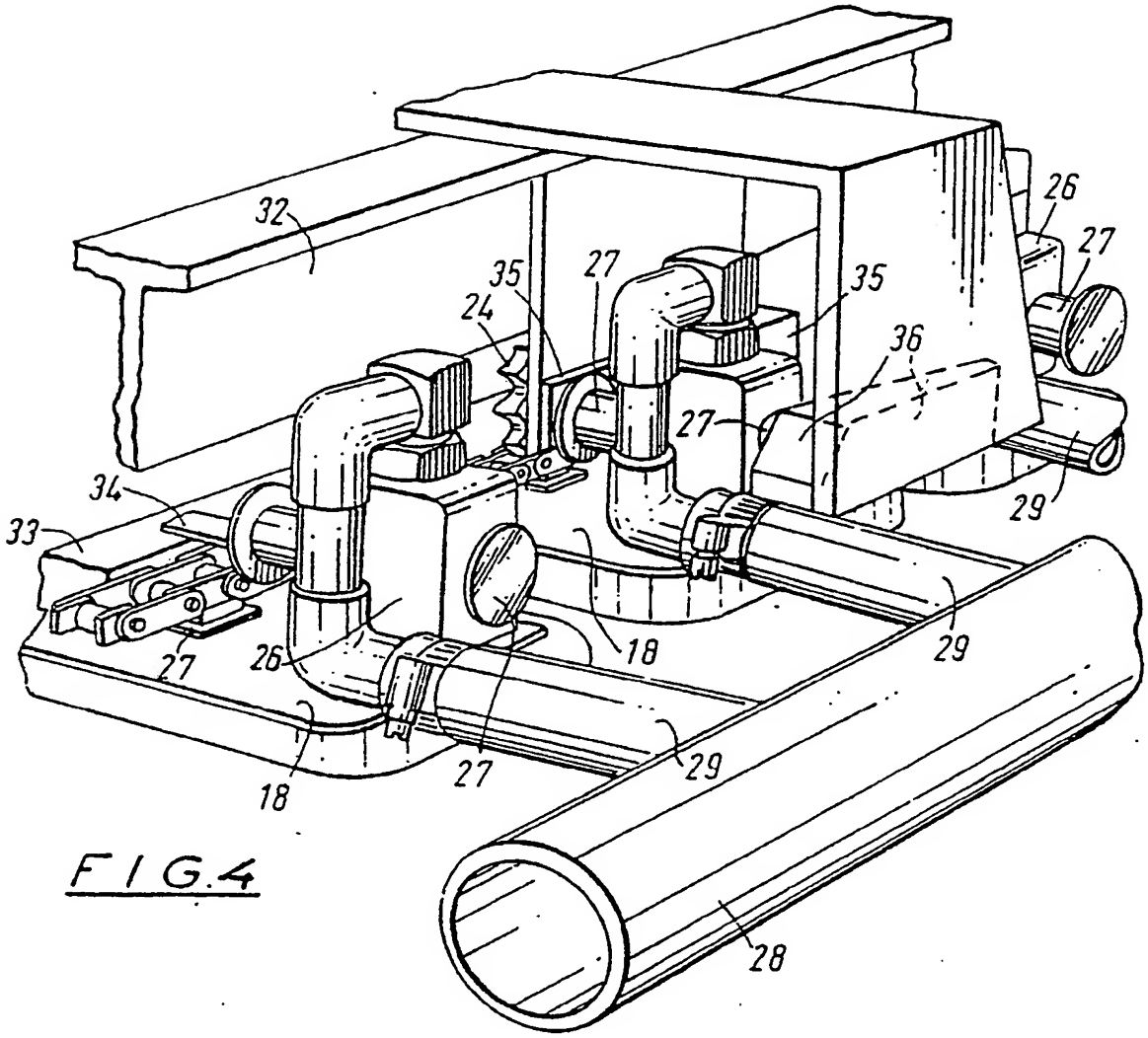

FIG.4

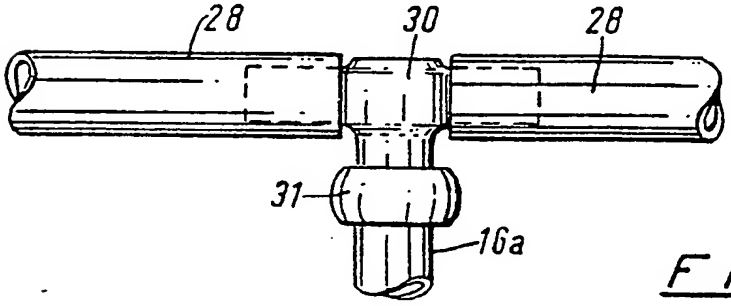

FIG.5

BUREAU OMPI WIPO INTERNATIONAL

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INTERNATIONAL SEARCH REPORT

International Application No PCT/N083/00048

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [5]

According to International Patent Classification (IPC) or to both National Classification and IPC 3

B 08 B 9/08, B 63 B 59/10, B 25 J 5/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	B 08 B 9/00,08-12; B 63 B 57/00, 59/06,10; B 62 D 55; B 25 J 5/00, 19/00
US Cl	180:9,10,901; 305:9,10,16-60

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 1 581 849 (N MADSEN) 20 April 1926	1-8
X	US, A, 3 991 842 (LARSEN) 16 November 1976	1-8
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A	DE, A, 2 032 231 (GEHOMAT, GISS & HOFNER oHG) 30 December 1971	
A	US, A, 3 960 229 (SHIO) 1 June 1976	
A	US, A, 3 973 711 (PEREGO) 10 August 1976	
A	GB, A, 989 742 (K KONTANI & E KONTANI) 22 April 1965	

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [3]	Date of Mailing of this International Search Report [9]
1984-05-28	1984 -06- 15
International Searching Authority [1]	**Signature of Authorized Officer [10]**
Swedish Patent Office	Folke Svensson

V.H.

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